NGNP Component Test Facility Test Loop Pre-Conceptual Design

Executive Summary

December 2008

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AREVA NP Inc.,

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1.0 INTRODUCTION

This report summarizes the AREVA High Temperature Gas Reactor - Component Test Facility or CTF test loop pre-conceptual design performed by the AREVA NGNP team for the Battelle Energy Alliance (BEA), the Management & Operating Contractor of the Idaho National Laboratory (INL) as part of the Department of Energy's (DOE) NGNP Project. The CTF test loop preconceptual design is fully documented in the AREVA document CTF Test Loop Pre-Conceptual Design report [1].

2.0 CTF PRE-CONCEPTUAL DESIGN OBJECTIVES

DOE's NGNP Project, as authorized by the Energy Policy Act of 2005, will develop and demonstrate a first-of-a-kind very-high-temperature gas-cooled nuclear system with the capability to generate electrical power and demonstrate nuclear hydrogen production. A key activity assumed to be necessary for completion of the NGNP project is the development of a large scale test facility. This facility will support development of high temperature gas thermal-fluidic technologies as applied in heat transfer and transport systems in High Temperature Gas-cooled Reactors (HTGRs).

The overall objectives of this project include:

- Prepare pre-conceptual design of the CTF test loops to provide high temperature, pressure and flow conditions defined in the NGNP Technology Development Road Maps (TDRMs) [2] and associated Test Plans (TPs).
- Design the CTF test loops and define strategies for construction and commissioning for these loops that satisfy the TDRM and TP requirements and will support the integrated test schedule.
- Design the CTF test loops for long term usage by the HTGR community for commercialization the technology

The purpose of INL in authorizing the pre-conceptual design summarized herein is two-fold:

- 1. Assist INL in focusing the technical scope and priorities of research & development activities for the NGNP.
- 2. Provide INL a basis for subsequent development of the technical and functional specifications for the Component Test Facility.

The CTF test loop pre-conceptual design as performed by AREVA within the authorized work scope and as reported herein are also consistent with the corresponding elements of the Phase I scope of work defined for the NGNP Project in the Energy Policy Act of 2005.

3.0 SCOPE OF WORK

The Scope of Work assigned to the AREVA NGNP team consisted of the preparation of the test loops preconceptual design to accommodate the test configuration supporting the Test Plans for NGNP Critical Structure System and Components (SSC)s, as well as, a generic testing envelope to facilitate future testing needs. The design information will include initial system level equipment lists, design specifications, Process Flow Diagrams (PFD)s and Process and Instrument Diagrams (P&IDs), schematics and layouts, and appropriate details of the major systems. The AREVA CTF test loops pre-conceptual configuration consists of two independent high



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temperature helium loops that provide the required test conditions established for development and testing of the NGNP components. The test allocation will be based on the required key performance parameters (e.g. helium flow rates, dimensions) established by the TDRM and TP process. The level of design detail in the test loop preconceptual design report (PCDR) will be sufficient to define the facility functional requirements, develop preconceptual design cost estimates, and provide input to the development of the CTF Conceptual Design.

The majority of the design effort under this scope will be to develop the large test loop design because an existing medium size loop design exists that can be made available to support the development of the CTF conceptual design subject to the conditions of this scope of work. Additional details related to a medium size test loop are provided without inclusion of intellectual property. The technical and functional requirements for performance test (e.g. flow induced vibration, materials performance, and seals leak rates) instrumentation are included in the PCDR, but not the specifications or equipment selection. In addition, the pre-conceptual test loop design identifies any R&D needed for the test loop components, and instrumentation and control systems.

AREVA recognizes that data collection and data quality control are the primary deliverable from the CTF. Extensive attention will be given during this pre-conceptual design to formulation, collection, fidelity and repeatability of test results.

Key work elements in this scope of work are as follows:

- Development of the CTF test loop System Requirements Manual
- Develop CTF test loop pre-conceptual design
- Identification of R&D needs of the test loop and project risks
- Test loop cost estimate (reported separately)
- Project schedule (reported separately)
- CTF test loop preconceptual design report.

The CTF test loops' designs are based on an existing and past experience with high temperature helium test loop configurations. These designs include the French HELITE loop, the German KVK loop and the Japanese HENDEL loop. The AREVA CTF recommended test loop configuration is further adapted to meet the required test conditions defined by the NGNP TDRM and TP activity.

4.0 AREVA CTF DESIGN TEAM

AREVA, as the lead contractor for this work scope, has the overall project responsibility. AREVA has assembled a team with subcontractor s to support the CTF pre-conceptual design work. The team possesses the key technical competencies needed to cover the full breadth and scope of the CTF project including final design, construction, and operations.

The AREVA CTF team includes Burns & Roe, and Mitsubishi Heavy Industries (MHI). The functional CTF design team organization is shown graphically in Figure 4-1.



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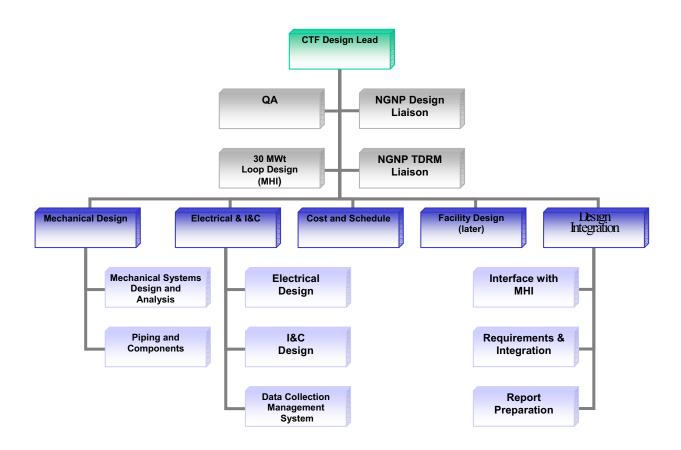


Figure 4-1: AREVA CTF Design Team Organization

5.0 CTF PRE-CONCEPTUAL DESIGN OF TEST LOOPS

The DOE-AREVA work plan governing CTF pre-conceptual work specified that the design be based on previous work performed by AREVA ([3] and [4]) that provided a recommendation for CTF loop designs and configurations. The size and the general performance characteristics of the test loops were established in References [3] and [4] further validating by the TDRM and TP test parameter requirements. The CTF test loops designs presented are based on MHI and AREVA past experience with design and constructions of high temperature helium test loop facilities. These facilities include the French HELITE loop, the German KVK loop, and the Japanese HENDEL loop. The AREVA CTF design team builds upon previous successful test loop experiences. The team will optimize the parameters and upgrade the test loop configurations to deliver the required test conditions for the NGNP component tests, as defined by the recently completed NGNP technology development road mapping (TDRM) and test planning (TP) process.

The CTF test loop configuration will deliver the required helium chemical environment, temperature, flow, and pressure conditions necessary for materials testing, full and partially scaled component and subcomponent testing,



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instrumentation testing, and data for codes and methods verification and validation (V&V). The CTF is envisioned as a versatile and flexible high temperature helium test facility. I will have the added c capability to provide high temperature process heat to a nearby hydrogen production facility where the interfacing components and heat transport processes can be demonstrated.

The CTF test loops design consists of a 1 MWt test loop, a 30 MWt test loop, and the associated support systems as follows:

- A flexible 1 MWt test loop capable of producing representative high temperature, pressure, and helium chemistry and purity conditions for testing the compact Intermediate Heat Exchangers (IHX) modules and the NGNP instrumentation.
- The 1 MWt test loop is designed for multiple configurations including a single loop operation and double loop operations. This loop has multiple test sections (up to four) that can produce test conditions at high or medium helium temperatures, full pressure and moderate flow rates. The test sections designed for concurrent operations or maybe bypassed.
- A versatile 30 MWt test loop capable of producing representative high temperature, pressure and flow conditions for full-height and partially-scale IHX and helium steam generator testing. This loop is also capable of producing test conditions for major HTGR primary system components including the hot ducts (HD)
- The facility electrical distribution system to power the CTF electric heaters, and provide emergency standby power for loop shutdown and cooldown due to of a loss of off site power.
- Instrumentation, controls and data collection system to control and monitor the test loops' operations and collect high fidelity test data for subsequent engineering and scientific analyses.
- Facility interface requirements for test loops operations support systems that are not in the scope of AREVA work.

The proposed 1 MWt test loop and the 30 MWt test loop concepts are illustrated schematically in Figure 5-1 and Figure 5-2.

The 1 MWt test loop is a versatile double "Figure-8 configuration" test loop designed with a hot and a cold sections (leg) in the primary and secondary side of the loops. The loop circulators are located in the cold leg of each loop. This will allow low temperature helium circulator technology and minimize loop cost. This test loop can easily and cost effectively be reconfigured to provide various desired test conditions. Multiple high and medium temperature test sections are provided for concurrent operations. The unique configuration of this test loop allows simulation of the desired temperature, pressure, flow and chemistry conditions for steady state and transient tests as required by the test plan. The primary and the secondary side of this test loop are connected to the helium Purification System (HPS), which provides the desired helium chemistry for compact IHX testing.

The 30 MWt test loop provides the required pressure, temperature and flow conditions for full length IHX and helium steam generator testing. This loop has provisions for hot duct testing and connections for future reactor vessel core components testing, plate IHX testing, direct cycle gas turbine testing, and process heat applications.

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HIGH TEMP
HEAT EXCHANGER

MEDIUM TEMP
TEST SECTION

MEDIUM TEMP
HEAT EXCHANGER

PRECUPERATOR

MEDIUM TEMP
HEAT EXCHANGER

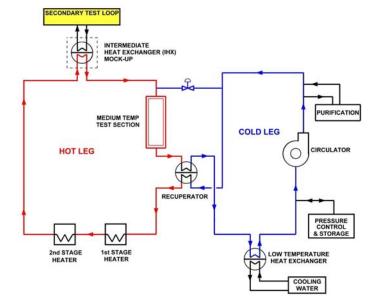
LOW TEMPERATURE
HEAT EXCHANGER

PRIMARY TEST LOOP

COOLING
WATER

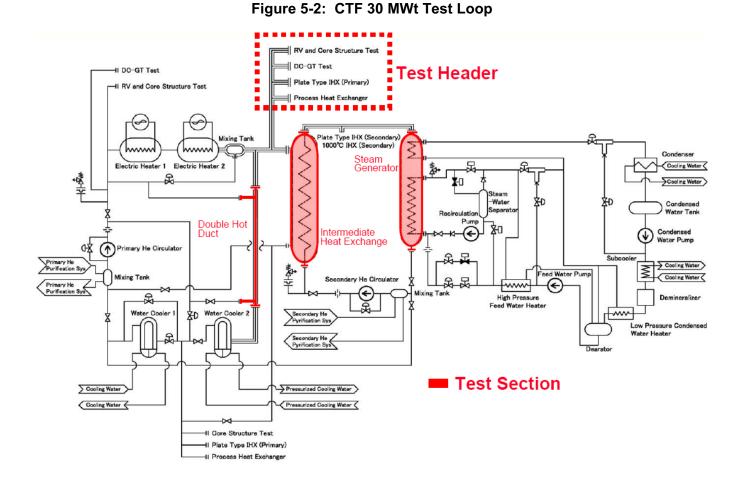
COOLING
COOLING

Figure 5-1: CTF 1 MWt Test Loop – Dual Loop Configuration



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The AREVA CTF test loops will fulfill the necessary short-term NGNP technology, component and material development test needs to advance the R&D and the longer term testing capability needed for qualification of components. The test loop design makes maintenance and modification and adjustments of the system more practical, since the equipment is distributed rather than tightly integrated. The test sections are designed for ease of access, operation and maintenance. The test loop design parameters are provided in Table 5-1.

The 1 MWt and 30 MWt test loops design and the operating parameters selected are assessed to be the best compromise to produce a variety of bounding normal and transient conditions for development and testing of the NGNP components and future HTGR development needs. The proposed design is considered as challenging, but feasible with reasonable R&D.

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Table 5-1: CTF Test Loop Operating Parameters

	1 MWt Loop	30 MWt Loop
High Temperature Test Section (°C)	500 to 1000 (primary side) 500 to 850 (secondary side)	800 to 1000
Pressure (MPa)	4 to 8	4 to 7
Flow (Kg/s)	0.04 to 0.4 (primary side) 0.04 to 0.4 (secondary side)	10
Power (MWt)	1 to 1.5	30
Temperature Transients	High Temperature Test Section: from 850 °C to 480 °C in 100 s (~220 °C/min), then 480 °C to 200 °C in 15 min (~19 °C/min), or 850 °C to 380 °C in 5 min 30 s	[±200 °C/min]
Pressure Transient	+0.9 MPa/min and - 0.38 MPa/min in 80 sec	Later
Flow Transients	+0.07 kg/s/s and -0.04 kg/s/s	Later

5.1 CTF 1 MWt Test Loop Design and Arrangement

The AREVA CTF 1 MWt test loop is a "double Figure-8," electrically heated high temperature test loop with helium as the working fluid on the primary and the secondary side. The primary and the secondary sides of the test loop are interconnected through an IHX mock-up. At the center of each test loop is an economizer / recuperator which separates the cold leg of the loop from the hot leg. The key benefit of a "Figure-8" test loop configuration is to improve the operating economy of the loop by reuse of the waste heat to heat the inlet flow stream to the loop heaters. In addition, the loop circulator is located in the cold leg to limit the cost of the circulator by using exiting technology and avoid development cost of high temperature circulator materials.

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The primary and the secondary test loop section are designed with two test sections each: 1) a high temperature test section, and 2) a medium temperature test section. In a combined configuration there are four test sections that can operate concurrently. Helium flow and temperature control capabilities are provided for each test section. Low, medium and high temperature helium to water heat exchangers are used to control gross helium temperature to each test section. These heat exchangers are also used for normal and emergency shutdown and cooldown of the test loops. In addition several cold to hot helium bypass lines are included for temperature control and to induce temperature transients.

The primary and the secondary test loops are thermally connected through the helium-to-helium intermediate heat exchanger (IHX) to simulate the NGNP indirect cycle primary and secondary configuration. The heat source for the secondary loop is the IHX. The circulating fluid in the secondary loop is helium as it is in the NGNP indirect steam cycle design.

Both the primary and the secondary loop are connected to a helium purification and filtration system to independently control the helium chemistry and purity in each loop.

The primary loop can be configured as a single loop by replacing the IHX with a high temperature helium-to-water heat exchanger as shown in Figure 5-3.

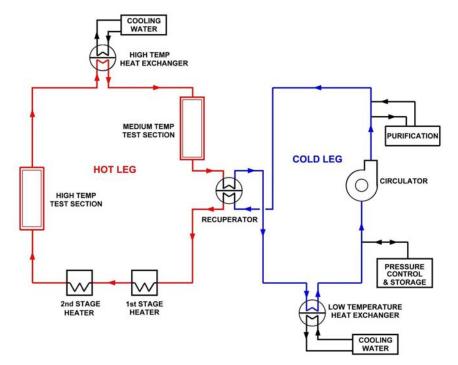


Figure 5-3: CTF 1 MWt Single Loop Configuration

In the single loop configuration only two test sections are operational; the high temperature test section and the medium temperature test sections of the primary loop. Similar to the dual loop configuration, the helium flow parameters to each test section can be independently controlled.

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The single loop configuration is capable of testing an NGNP IHX mock-up. This configuration is schematically depicted in Figure 5-4, and the high temperature test section is bypassed.

Each test section is individually designed (not within the scope of this work) to examine components and materials performance in a representative NGNP helium environment and chemistry. A typical test section piping arrangement is illustrated in Figure 5-5.

The helium chemistry is monitored and controlled by the helium purification system which has a chemistry and purity control feature. Helium chemistry (e.g. N₂, NO, NO₂, CO, CO₂, H₂, O₂) and purity can be controlled to create the test conditions specified in the preliminary test plans. Graphite dust cannot be completely removed from the test loop once it has been introduced. The graphite introduced may preclude future operability of the test loop - dust particle testing in the primary or the secondary test loop is not recommended. Consequently, provisions have been made to add a dedicated (tertiary) test loop (not shown-future design) using similar hot piping, circulator, and high temperature heat exchanger components between the primary loop and IHX. The dust test loop must be designed (not within the scope of present work) to test the effects of graphite dust on the IHX without contaminating the primary test loop.

COOLING WATER HIGH TEMP (IHX) **IEAT EXCHANGER** MOCK-UP PURIFICATION COLD LEG CIRCULATOR MEDIUM TEMP **TEST SECTION** RECUPERATOR **HOT LEG** PRESSURE CONTROL & STORAGE COOLING 2nd STAGE 1st STAGE WATER HEATER **HEATER** LOW TEMPERATURE

HEAT EXCHANGER

Figure 5-4: 1 MWt Single Loop Schematic (for IHX Mock-up Testing)

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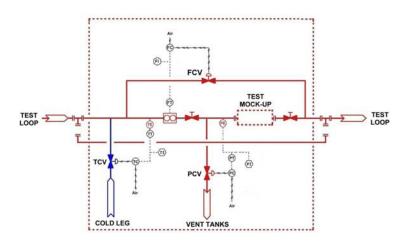


Figure 5-5: CTF 1 MWt Test Loop Typical Test Section

Major components of the CTF 1 MWt test loop are:

- Circulators One circulator in the primary and one in the secondary test loops provides the driving force to move the helium around the loops. Each circulator is located in the cold leg of the respective loop. The helium flow around the loops is controlled with the circulator's variable speed motor drive.
- Recuperator One recuperator per test loop segregates and the hot and cold legs of each test loop and maximizes the test loops' total energy efficiency.
- Electric Heater Banks There are two electric heater banks in the hot leg of the primary test loop. The first heater bank raises the helium temperature to 850°C and the second will elevate the helium temperature to the maximum loop temperature capability of 1000°C. The heater elements are individually controlled to provide fine temperature control of the helium.
- Heat Exchanger The test loop's high, medium and low temperature helium-to-water heat exchangers provide helium temperature control to the test sections and circulators. An additional function is to cooldown the loops in emergency conditions, such as a lose of off-site power.
- Helium Purification The helium purification system provides circulating helium purity and chemistry control. The HPS can independently control helium chemistry on the primary and the secondary side of the 1 MWt loop.
- Helium Supply and Storage The helium supply and storage system maintains the proper
 pressure in the test loop to accommodate normal leakage and allows for the depressurization of
 the test loops by providing helium vent tanks.



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The CTF 1 MWt test loop is designed to provide long term steady-state helium chemistry environment at temperature, pressure and flow conditions representative of the NGNP. In addition, the loop is capable of creating temperature, pressure and flow transient conditions in any one of its multiple high and medium temperature test sections. Such capability is made possible first and foremost by the unique design of the loop and second by the versatility of the digital distributed control system typically used by AREVA in control loops of modern industrial plants including nuclear plants. The Siemens T3000 digital distributed control system is specifically recommended for this purpose. All tests and loop operations are controlled and monitored from a single integrated control room. Local controls and indication devices are provided; the actual location and number of such devices will be defined during subsequent phases of the CTF test loop design.

Test loop operations and personnel safety has been one of the design objectives. The test loop control system is provided with safety features, such as automatic heater power run back, temperature reduction, and pressure reduction measures to protect the test loop from operating outside of its design limits. The test loop is equipped with safety relief valves to prevent loop over pressurization. In case of loss of electricity, a facility diesel generator (not in the scope of this design activity) will provide backup power to shutdown and cooldown the test loop.

All enclosed areas around the test loop are monitored for oxygen concentration limits and are ventilated, as helium asphyxiates. The test loop safety relief valves are vented high above the building exterior to prevent discharge into enclosed areas of the facility. A portion of the loop operates at high temperature. All pipes and heat exchanger surfaces are insulated to limit the exterior surface temperatures to 50 °C or less.

5.2 CTF 30 MWt Test Loop Design and Arrangement

The AREVA CTF 30 MWt test loop is an electrically heated loop with helium as the working fluid. The base configuration includes a primary and a secondary high temperature helium test loop designed to test full-height and scale helical coil helium-to-helium heat exchanger for performance verification and design qualification.

The primary test loop can provide representative high temperature helium conditions through a test header connection for the following tests:

- Hot duct
- Reactor vessel and core structures
- Direct Cycle Gas Turbine
- Plate type IHX (primary side), and
- Process heat exchange

In the tubular IHX test configuration the secondary side of the IHX can supply heat for the following tests:

- Plate type IHX (secondary side), and
- Helium steam generator with a super-heater section



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The steam generator test configuration on the tertiary side includes a full complement of standard feedwater heaters, feedwater and condensate pumps, steam piping, condenser, and the associated pumps, valves, tanks, water treatment system, and cooling towers. The tertiary conventional water and steam loop is designed for performance verification and design qualification of a high temperature helium steam generator design.

The primary and the secondary helium test loops are independently connected to the helium purification system to control helium chemistry and purity in each test loop.

Major components of CTF 30 MWt test loop are:

- Circulators One circulator in the primary and one in the secondary loop provides the driving force to move the helium through the test loops. Each circulator is located down stream of the water cooling heat exchanges, IHX, or the steam generator to limit the circulator inlet temperature and reduce the cost of the circulators.
- Electric Heater Banks There are two electric heater banks down stream of the primary loop circulator to raise the loop helium temperature to its maximum desired temperature. The first heater bank raises the helium temperature to 800°C, and the second will increase the helium temperature to the maximum loop temperature capability of 1000°C. A heater bypass line and a mixing chamber downstream of the heater banks will be used to refine the helium temperature control. The heater elements are individually controlled to provide additional temperature controls.
- Heat Exchanger The primary test loop includes a high pressure and a low pressure helium-towater heat exchange to reduce the helium temperature upstream of the circulators.
- Helium Purification System The helium purification system circulates the purified helium and controls helium chemistry. The HPS can independently control helium chemistry in the primary and the secondary test loops of the 30 MWt test loop.
- Helium Storage System The test loops' supply of helium and storage for the depressurization of the test loops are accommodated by the helium storage system.

The CTF 30 MWt test loop is designed to deliver a long-term, steady-state helium environment at the chemistry, temperatures, pressure, and flow conditions representative of the NGNP. In addition, the test loop is capable of creating temperature, pressure, chemistry and flow transient conditions in any one of its multiple high temperature test headers. Such capability is made possible by use of cold and hot helium mixing and a robust digital distributed control system typically used by AREVA in modern industrial plants. The Siemens Power Plant Automation System T3000 digital distributed control system was specifically chosen for this application. The T3000 system is a modern distributed control System for power plant automation, and will be used in the new nuclear power plants proposed by AREVA for the control and monitoring of the non-safety related systems. All tests and test loop operations are controlled and monitored from a single integrated control room. Local controls and indication devices are also provided; the actual location and number of such devices will be defined during subsequent phases of the loop design.

Test loop operations and personnel safety has been one of the design objectives. The loop control system is provided with protective features, such as heater power run back, temperature reduction, and pressure reduction measures to protect the test loop from operating outside of its design limits. The loop is also equipped with



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rupture discs and safety relief valves to prevent over-pressurization. In case of loss of off-site power, a diesel generator (not in the scope of this design activity) will provide emergency power to shutdown and cooldown the loop, and maintain essential power to the CTF.

All enclosed areas around the test loop are monitored for oxygen concentration limits and are ventilated, as helium asphyxiates. The test loop safety relief valves are vented high above the building exterior to prevent discharge into enclosed areas of the facility. A portion of the loop operates at high temperature. All pipes and heat exchanger surfaces are insulated to limit the exterior surface temperatures to 50 °C or less.

6.0 CTF ELECTRICAL SYSTEM DESIGN

The CTF's electrical supply to the building and distribution within the building will conform to standard industrial facility electrical design practices. Main electrical supply to the facility is provided by a new utility substation containing a 55 MVA 230 kV/13.8 kV stepdown transformer. Medium voltage (13.8 kV) from the substation stepdown transformer is routed to a medium voltage rated switchgear inside the CTF. The voltage is further reduced to 480 VAC to power the 1MWt loop switchgears and for other facility loads. The medium voltage switchgear will be used to energize the 30 MWt loop heaters and circulators, which are consumers of large power loads.

Switchgear and circuit breakers are 100 % rated. The electronically controlled breakers and protective relays provide breaker status and power quality measurements both to local and remote terminals with supervisory control and data acquisition communications capability. Additionally, electronic circuit breakers allow for selective zone interlocking, which can eliminate breaker tripping intentional delays on due to electrical faults. This capability allows fault isolation to the nearest breaker for full coordination - remaining fully selective with downstream devices.

7.0 CTF TEST LOOP INSTRUMENTATION, CONTROLS AND DATA STORAGE SYSTEM

The CTF control computer and data acquisition system is common to both the 1 MWt and 30 MWt test loops, and is based on Siemens' Power Plant Automation (SPPA) T3000 digital distributed control system.

Three sets of input/output (I/O) cabinets are provide - one for each test loop and one for the balance of plant (BOP) usage. The I/O cabinets' cables will run to the CTF devices. The I/O cabinets will be located as close to the test loops as possible to aid easy of modifications for future test sections requirements.

A large number of I/O points will be provided for the test loops to monitor and control operations and to collect data. This will ensure an ample number of spares for future expansion and for multiple test loop configurations. The number and type of I/O points will be finalized during detailed design. I/O points for the BOP cabinets are not yet determined.

Two Automation Processor (AP) cabinets are planned. One cabinet for 1WMt test loop, and one for the CTF BOP equipment. The AP cabinets will be located near the I/O cabinets and are connected via the Process Field Bus (ProFiBus). Data from the I/O cabinets are processed by the AP cabinet equipment and places the processed data on the automation highway. For the 30 MWt loop, IO cabinets are connected to a Programmable Logic Controller (PLC) and the PLC is connected to the Automation Bus. In case of a power failure, redundant, battery backup, uninterruptible power supplies (UPS) are provided to assist in an orderly shutdown of the test loops and to ensure no data is lost.



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The Application Server is fault tolerant, redundant dual-processor and is located in the network cabinet. Application software runs on these servers. The system has a large hard drive, which can store data for a long time. A PI-System is used for long term historical data storage and retrieval, which the data readily available to authorized personnel anywhere on the enterprise.

Automation and Application highways communication networks connect all the devices via fiber optic cables. Ethernet drops are provided to the various devices. Networking equipment cabinet will be located in the equipment room.

Two workstations are provided in the CTF control room. Each workstation can control both the 1 MWt and 30 MWt test loops and the BOP loops using soft controls. Three monitors will be provided for each workstation, providing flexibility to control the test loops. Temperatures, pressures, flows and other parameters in the primary and secondary loops are controlled from these workstations. Screens can be programmed to show simple test loop P&ID with temperature, pressure and flow at selected locations. An operator can place the mouse cursor on a displayed piece of equipment. A controller will open an operations menu to allow the operator to select the desired mode of operation, such as, manual- automatic, open-close or start-stop, to control pressure, temperature and flows in the test.

An automatic shutdown routine will be incorporated to protect against temperatures, pressures and flows excursions, and place the test loop in a safe condition.

Any abnormal condition will be displayed on a separate workstation alarm screen with its priority. All the alarms (audible and visual) are printed on the alarm printer for operator reviews.

An additional engineering workstation is planned in the control room to permit authorized system software and configuration modifications. This workstation has two monitors, one monitor shows existing configuration and the second monitor is used for making modifications.

Various instrumentations are used to control and monitor the test loops and the test sections. Some are listed below:

Helium mass flow in the loops is accurately measured using a Coriolis mass flow meter at the high temperatures in the test loop. Type K or N thermocouples will be used. Most thermocouples will require thermowells. Rosemount pressure measurement transmitters or equivalent are recommended with remote seals or long tubing runs..

The SPPA T3000 control system is robust, achieved through the selected software architecture with the runtime containers and function blocks. The various test loop points temperatures, flows and pressures are controlled by the control system. Operating signals are sent to the appropriate valves, heaters and circulator speed to maintain the test parameters. The control system can be programmed to initiate an automatic startup and shutdown the test loop, initiated by the operator.

The control algorithms (software) can be easily modified on the engineering work station. Test loop control algorithms can be selected at the operator station to induce bounded temperature, pressure or flow transients in each test section.



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Test loop control system malfunctions due to temperature, pressure or flow excursions, will automatically trip the test loop protection system and place it in the safe condition. The protection system uses separated sensors and hardware than the control system, which provides redundancy.

An emergency, hard wired, manually operated control board is provide in the control room of the 30 MWt test loop, which will place the test loop in a safe condition due to unexpected network or the computer control system failure.

8.0 TEST LOOP LAYOUT

The CTF components are located in dedicated enclosures within the facility. The CTF buildings and superstructures were not part of this design activity. However, the proposed test loop layout requirements are provided to ensure optimum facility efficiency and operational capability. The overall facility design as envisioned by the test loop designers includes independent locations for dedicated to the 1 MWt test loop and the 30 MWt test loop. The 1 MWt test loop will be needed far in advance of the 30 MWt test loop. Therefore, a separate 1 MWt CTF building must be erected and operated, while the 30 MWt test loop is designed and construction is under way.

The design of the test loops are such that flexibility and multiple configuration options are built into the initial design. Therefore, the plant layout of these loops must be consider and account for design flexibilities. Test loop modifications and reconfigurations are possible and would be necessary on a regular basis during their operating life.

Both the 1 MWt and the 30 MWt test loops operate at high pressure during normal and transient cycles. Some equipment surface temperatures are limited to less than 50°C. The loops are divided in three energy zones due to very high operating temperatures and are defined as follows:

- High Energy Zone This zone may contain equipment and piping under high temperature and pressure.
 This zone has the highest energy release in case of an accident. Therefore, the equipment in this zone
 must be located in heavily bunkered area. Access would be restricted during operations to mitigate
 damage to plant personnel and equipment.
- Medium Energy Zone This zone may contain loop equipment and piping under high pressure with medium or low temperature streams. The equipment in this zone must be supported against pipe whip during a pipe break. The personnel access must also be limited during operations.
- Low Energy Zone This zone contains loop equipment and piping under low pressure and temperature
 conditions. No special plant equipment layout or personnel access requirements are necessary for this
 zone.

The 1 MWt test loop has a much smaller footprint than the 30 MWt test loop. However, the test loop configuration options for the small loop and the number of test sections are larger. The plant layout must accommodate such requirements. For example, the test sections of the 30 MWt test loop are tall (over 25 meters). The large test pieces include a full height tubular IHX, compact IHX, hot duct pieces, steam generator, provision reactor vessel internal and core structure tests, connection for direct cycle gas turbine tests, and a provision for supply of process heat to the hydrogen plant.



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9.0 SAFETY AND QUALITY

The CTF safety concept utilizes defense-in-depth provisions to protect plant systems, structures and components, and the operating personnel health and safety. The loop safety philosophy includes the following defense-in-depth measures:

- Use of consensus industrial design standards (ASME, IEEE, NEC, etc.)
- Passive and active accident prevention measures
- Accident mitigation measures
- Administration and procedural controls

The AREVA CTF test loop safety concept primarily relies on robust design and high quality equipment specifications that provide high design margins. The test loop components are designed to the national codes design standards provided by the ASME, IEEE, NEC, and TEMA.

In addition to design, the operation of the loop is constantly monitored and automatically evaluated to detect unsafe conditions. The key test loop operating parameters are continuously monitored for anomalies and operating conditions that are approaching their safety limits. The plant control systems will then react and initiate a power runback or a loop shutdown procedure to a safe condition. Passive safety measures are the next level incorporated into the design. The test loops utilizes automatic safety relief valves and rupture discs to protect against over pressurization. Insulating material is used to protect plant personnel and equipment from high temperatures.

The plant areas are divided in three zones according to the amount of energy available for release. The High Energy Zones are protected by placing the equipment in a heavily fortified bunkers and administratively limiting personnel access. The Medium energy Zones are protected by structural steel components and administratively limiting personnel access. The Low Energy Zones do not require any special mitigation measures.

The CTF test loops utilize helium, which can asphyxiate. Enclosed areas of the plant are monitored for oxygen content and presence of excessive amounts of helium. Notification and evacuation alarms are used to alert personnel. Following the completion of the facility structural design, evacuation routes will be marked and evacuation exercises will be mandated by procedure.

10.0 PLANNING FOR COMPLETION OF CTF PROJECT

The AREVA team pre-conceptual design work was limited to the CTF test loop design. Therefore, the depth and level of detail associated with the facility cost estimate and project schedule is limited to that previous work - see [4].



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10.1 Capital Cost

The CTF capital cost estimate during the next design phase (after completion of the pre-conceptual) will be in accordance with the AREVA Work Breakdown Structure (WBS) for the CTF activities. The WBS covers the entire CTF project lifecycle, but only the CTF test loop design capital cost has been provided.

The capital cost estimate will not be included in this summary report. This information will be submitted to INL/BEA separately.

10.2 Project Schedule

The CTF project schedule encompasses the time span beginning with the project conceptual design phase, concurrent with supporting the NGNP research and development activities identified in the TDRM report, plant construction activities, long-lead component procurement including steps to be taken for key hardware acquisition, plant commissioning, testing and initial operation, leading to facility turn-over and operations.

The CTF high level project schedule is shown in Figure 10-1. A more detailed project schedule is provided separately.

Key elements of the AREVA NGNP project schedule consist of:

- 1. Plant Design
- 2. Research and Development Interface
- 3. Test Equipment Manufacturing and Supply
- 4. Procurement
- 5. Construction
- 6. Commissioning and Turnover
- 7. Facility Operations

CTF 1 MWt test loop will be completed and operational in the first 24 months. The construction of the large loop will continue on the same site and will be completed in 60 months from the start of the project. The CTF small loop will be operational while the large loop is under construction.

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Figure 10-1: CTF High Level Schedule

11.0 RISK MANAGEMENT AND R&D

Risk management is a continuous process that identifies, analyzes, prioritizes, mitigates and tracks project risks. The scope of risk management applies to all phases of the CTF project: design, construction, commissioning and turnover, and operation.

Research and development is closely related to the risk management process. Successful development of the NGNP will depend to a large extent on the research performed to address the technical risks identified in the risk management process. Additionally, the relationship between risk management and R&D is iterative. An identified risk may be mitigated by focused R&D aimed at resolving the risk. Whereas, R&D, by its very nature, will explore the limits of current knowledge and experience, which in turn identify additional risk. It must be recognized that R&D may only resolve technical issues, and that risk management also includes non-technical risks (e.g., social, political, financial etc.).

AREVA expects the risk associated with the CTF to be limited to normal construction risk. The facility is a standard industrial complex and the risk of construction of such facility well known and acceptable. The risks associated with the design of the test loops are minimal. The 1 MWt test loop is modeled after an AREVA test loop of similar configuration, which is designed to European standards. If this design is acquired, it will be converted to U.S.A. codes and standards. Facility construction can commence shortly thereafter.

12.0 CONCLUSIONS/RECOMMENDATIONS

The CTF pre-conceptual design has been completed. The test facility provides the test conditions identified through a technology development road mapping activity performed by AREVA. The test loops proposed



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includes a small, but versatile and highly configurable loop. The multiple test sections provide NGNP representative temperatures, pressure and conditions capable of simulating transient conditions. This test loop can be operational within two years of contract award given the complete design documentation available from AREVA.

The CTF also includes a large 30 MWt test loop that is essential in qualification of full-height scaled components, such as the IHX and the helium steam generator. The AREVA team has designed and manufactured a similar large test loop and is fully confident that it can be built again for the NGNP.

13.0 REFERENCES

- 1. AREVA Document 12-9097512-001, NGNP CTF Test Loop Pre-Conceptual Design Report
- 2. AREVA (AFS) Document TDR-30001031-000, NGNP Technology Development Road Mapping Report.
- 3. AREVA Document 12-9072397-000, High Temperature Gas Reactor Component Test Facility Mission Needs and Requirements.
- 4. AREVA Document 12-9076931-000, NGNP Component Test Facility Conceptual Configuration, Cost, and Schedule Estimate.